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The link between green taxation and economic growth on CO_2 emissions: Fresh evidence from Malaysia

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ABSTRACT

This paper explores how carbon taxation and economic growth affect environment hazards in Malaysia using time series data over the period 1974–2010. We applied cointegration and causality approaches to determine the long-term cointegration and direction of causal relationship between these variables. Based on the results, we found the cointegration relationship between the variables. Furthermore, we noted that although Kuznets' theory, i.e. inverted-U shaped curve between economic growth and CO_2 emissions is valid for Malaysia, the carbon taxation policy is ineffective to control CO_2 emissions. The causality analysis revealed that there is a bidirectional relationship between carbon tax and CO_2 emissions. Economic growth Granger causes CO_2 emissions and carbon tax Granger causes economic growth. To enhance the awareness concerning pollution issues, governments should rely on alternative instruments that may give benefit to the taxpayers and reduce pollution, which is the pivotal issue to be tackled globally.

Contents

1. Introduction

Since the late 1980s, the state of the environment has been one of the most important issues facing society. The industrial civilization is a major cause of the extensive damage to the environment, and, economic losses from natural disasters, such as extreme weather-related events, are occurring at an alarming rate. With countries racing to achieve developed economy status, the new pollution is the result of internal combustion engines, power stations and even chlorofluorocarbons (CFCs). Realizing the importance of this issue, increased attention is being given to combat these environmental hazards. Likewise, pressure groups have been campaigning vigorously for an improvement in the quality of the environment. Climate change, water, energy and pollution are among the most pressing concerns for humanity at both the national and global levels. With the establishment of the Kyoto Protocol in 1997 by the United Nations Framework Convention on Climate Change (UNFCCC), many governments have exerted efforts to reduce their CO_2 emissions. Thus to support the effort to protect

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the environment, Malaysia ratified the Kyoto Protocol on 4th September, 2002.

However, it is worth highlighting that, in 1967, Malaysia enacted the Petroleum Taxation through which tax is imposed on income earned from the winning of petroleum. Specifically, winning of petroleum refers to any mineral oil or relative hydrocarbon and natural gas existing in its natural condition and casing head petroleum spirit. Years later, Malaysia introduced the 1974 Environmental Quality Act to show their concern in protecting the environmental quality. Although this tax was initially imposed to gain revenue, it can also be seen as the first step taken by the Malaysian government to address issues relating to the environment. Globally, countries are looking at the best ways to show their concern regarding environmental hazards, which are the result of development activities. The imposition of carbon tax, green tax, energy tax and petroleum tax are some of the methods used to reduce environmental damage. For instance, carbon tax is imposed on the carbon content of goods or directly on the emissions of greenhouse gases, which is one of the alternatives to lower the level of pollution produced by the industries ([1]). In addition, carbon tax is paid on the consumption of energy products, such as fuel, or on each extracted fossil fuel ([2–4]). Despite having different names, these taxes have been introduced for the purpose of overcoming the negative impact resulting from the use of non-environmental products and services.

This study contributes in existing literature by investigating the relation between carbon tax and CO_2 emissions using the time series data for the period of 1974–2010. We have engaged structural break unit root test to test the integrating properties of the variables. The cointegration amid the variables is investigated by using the ARDL bounds testing. The direction of causal association among the variables is investigated by using the VECM Granger causality approach. We find that the relation between economic growth and CO_2 emissions is inverted U-shaped but environmental taxes control CO_2 emissions ineffectively. The feedback effect is found between carbon tax and CO_2 emissions.

2. Literature review

In support of this, based on the Environmental Kuznets curve (EKC), as per capita income rises, environmental destruction increases. After attaining a critical level of economic growth, the country will become more aware of the need to protect the environment. This is the case for a developed country, in that the moment the country has achieved developed status; it will become more concerned about environmental issues. The earliest wave of research in this area focused on the nexus between carbon emissions and economic growth, providing conflicting results, some of which are in favour of the EKC theory and others against ([5–12]). However, it is difficult to pinpoint the direction of a relationship, that is, whether the influence proceeds from economic growth to carbon emissions or the reverse, or in both directions. Tiwari [13] establishes four sets of testable hypotheses that have been proven from past research, as presented in Table 1.

Based on selected literature listed on Table 1, the direction of the relationship varies such that there is no uniformity in the direction of the relationship. However, what we can agree on is that a strong relationship exists between carbon emissions and economic growth. Given the profound relationship between carbon emissions and economic growth, it comes down to the efficient tools that can be implemented by the government to reduce pollution problems. On the one hand, imposing taxation on carbon is considered to be one of the most efficient tools for combating environmental problems. On the other hand, the idea of imposing carbon taxation to economic activities may be opposed by the state government. For instance, when the government needs to fulfil the requirements for a sustainable forest management by imposing other environmental and ecological restrictions on logging companies, it might be reluctant to do this as this could result in lower revenue from the companies ([25]). However, studies investigating the validity of this relationship are still scarce, as most of the studies mentioned earlier focus on analysing the relationship between carbon emissions and economic growth. Thus, this opens a channel of research in examining whether imposing tax will have significant impact on carbon emissions. As a result it will later affect the growth performance. Some scholars (Liang et al. [26,4,27]) believed that carbon taxes imposed by the government have a significant effect on emissions reduction although the impact might be minimal. This shows that taxes imposed on economic activities that lead to environmental risk help to raise awareness and may motivate taxpayers to find alternative ways to dispose of waste from the companies. While carbon tax is considered to be the solution to combating the emissions problem, it has a negative impact on the economy.

Liang et al. [26], and Lin and Li [4] point out that the impact of carbon tax may depend on the economic conditions of an economy. For instance, an analysis concerning the impact of carbon tax on CO_2 emissions in Denmark, Finland, Sweden,

Table 1
Selected literature on EKC indicators.

Hypothesis	Author	Country	Period	Causality direction
Growth	Lee and Chang [14]	Taiwan	1954–2003	CE/EC → EG
	Ang [15]	France	1960–2000	CE/EC → EG
	Ozturk and Acaravci [16]	Turkey	1968–2005	CE/EC → EG
	Binh [17]	Vietnam	1976–2010	CE/EC → EG
	Shahbaz et al. [8]	Turkey	1970–2010	CE/EC → EG
	Shahbaz et al. [7]	Romania	1980–2010	CE/EC → EG
Conservation	Fati et al. [18]	New Zealand, Australia, India, Indonesia, Philippines and Thailand	1960–1999	CE/EC ← EG
	Tiwari [13]	India	1971–2005	CE/EC ← EG
Feedback	Glasure [19]	South Korea	1961–1990	CE/EC ↔ EG
	Jumbe [20]	Malawi	1970–1999	CE/EC ↔ EG
	Yoo [21]	Korea	1970–2002	CE/EC ↔ EG
	Shahbaz et al. [22]	Pakistan	1972–2011	CE/EC ↔ EG
Neutral	Yu and Jin [23]	United States	1974–1990	No relationship
	Stern [24]	United States	1948–1994	No relationship

Note: CE – carbon emission, EC – energy consumption and EG – economic growth.

The Netherlands and Norway, indicated that carbon tax significantly affects economic growth in Finland, but it is not significant in the other countries. This may be caused by the different impacts of carbon taxes in different countries, which mainly derive from the policy approach and different rates imposed. Developed economies, such as Australia, are struggling to reduce global emissions by imposing carbon taxes. However, the effect is deemed too small, as many developing countries have ignored the environmental protection in order to achieve their aim to become developed economies ([1]). Furthermore, carbon tax is considered to be a burden, specifically for developing countries. This is because, when the tax is imposed, it will increase the cost of development, which, in turn, might lead to a distortion in the economic growth. Furthermore, Kiuila and Markandya [28], and Zhou et al. [29] report that carbon tax is able to produce a positive impact when the tax is designed to shift the burden from the labour force or household income to environmental pollution.

However, the imposition of carbon tax might have a direct impact on the economy and growth of all countries in that it would be followed by higher CO_2 emissions as a result of more production industries and household consumption. Since the aim of carbon tax is to reduce CO_2 emissions, it is noted that this will distort economic growth. However, to some extent, this is not the case when the negative impact on economic growth from carbon tax is not obvious for the reason that the tax revenue is incorporated into an economic system to offset economic growth loss. Supporting these results, Löfgren and Nordblom [30], based on a survey conducted in Sweden, suggest that using CO_2 tax as an important climate policy will be more politically feasible and legitimate when the focus is given to the climate change problem. Pardhan and Gosh [31] investigated the impact of carbon tax on growth of CO_2 emissions in India. They reported that reduction in CO_2 emissions is reduced by implementing carbon tax. Oueslati [32] unveiled that impact of carbon tax on CO_2 emissions depends upon the magnitude of carbon tax reforms. But Friedman et al. [33] exposed that initially carbon tax reduces CO_2 emissions effectively but after a certain level its effect dies out. Bruvoll and Larsen [34] noted that carbon tax significantly improves the environmental quality in Norwegian economy. They exposed that a 3.2% growth of CO_2 emissions can be reduced by increase in carbon tax by 1% if all else is same. Surprisingly, Allan et al. [35] exposed that carbon tax revenues are used to meet government expenditures and environmental quality is not improved in Scotland.

In light of the above discussion, this study aims to examine the impact of carbon tax on carbon emissions and economic growth in Malaysia from 1976 to 2010. This study contributes to the literature by focusing on the discussion of issues, which have not been explored in previous studies, specifically in Malaysia. The central idea is that the imposition of carbon tax is vital for the government as an alternative way to collect tax as well as to combat environmental problems. Furthermore, the imposition of carbon tax also seems to affect the growth of the country.

The remainder of the study is organized as follows: Section 2 describes the model construction and methodological framework; the results and their discussion are explained in Section 3, and Section 4 presents the conclusion and policy implications.

3. Model construction and methodological framework

The data used in the study are annual observations obtained from two data sources covering the period from 1976 to 2010. The carbon dioxide emissions (CO_2) data are extracted from World Development Indicators [36]. Meanwhile, data concerning carbon tax (CTax) and GDP per capita, measured at the 2005 constant prices, have been obtained from the Department of Statistics. The functional relationship is as shown in Eq. (1):

$$CO_{2t} = f(\mathrm{CTax}_t, \mathrm{GDP}_t, \mathrm{GDP}_t{}^2) \tag{1}$$

where CO_2 is referring to environmental hazards in (kt), CTax is carbon tax proxy to green taxation, GDP is proxy for economic growth and GDP^2 is GDP squared. All data are measured in Ringgit and transformed to logarithm. Cong et al. [37] and Cong and Shen [38] also supported the use of log-linear specification for empirical analysis and formations as shown in Eq. (2):

$$\ln CO_{2t} = \beta_1 + \beta_2 \ln \mathrm{CTax_t} + \beta_3 \ln \mathrm{GDP_t} + \beta_4 \ln \mathrm{GDP_t}^2 + \mu_t \tag{2}$$

where $\ln CO_2$ is the natural log of CO_2 emissions, $\ln \mathrm{CTax}_t$ is natural log of carbon tax, $\ln \mathrm{GDP}_t$ ($\ln \mathrm{GDP}_t^2$) is the natural log of real GDP per capita (natural log squared of real GDP per capita) and μ_t is a residual term assumed to be white noise.

3.1. Unit root tests

In this study, we use the Augmented Dickey–Fuller [39] and Phillips–Perron [40], which are low, powerful unit root tests, for the stationary level of each variable used. As can be seen from Fig. 1, the plots of CO_2, CTax and GDP appear to show structural breaks and indicate more reason to use endogenous powerful unit root tests with structural break(s). In addition, in some circumstances, the traditional residual based unit root test can be biased, and, to reduce the biasness, the structural break(s) unit root test is the best solution. First, we employ Zivot and Andrew [41] with a single unit root test to capture the time trend of the break date. Although the ZA unit root test is able to capture a single structural break, in our case, we need more powerful and more break indications through the series. Therefore, the suitability test is Clement et al. [42], which is generally referred to as CMR double mean shift breaks. The CMR test is able to capture double structural breaks in the mean value using an innovative (IO) and additive outlier (AO) ([43]). The null hypothesis for CMR is

$$H_0 : x_t = x_{t-1} + a_1 \mathrm{DTB}_{1t} + a_2 \mathrm{DTB}_{2t} + \mu_t \tag{3}$$

$$H_1 : x_t = u + b_1 \mathrm{DU}_{1t} + b_2 \mathrm{DTB}_{2t} + \mu_t \tag{4}$$

where DTB_{1t} is the pulse variable that equals 1 if $t = TB_{i+1}$ and zero otherwise; $\mathrm{DU}_{it} = 1$ if $\mathrm{TB}_i < t$ ($I = 1, 2$) and zero otherwise; and TB_1 and TB_2 is the modified means over the time periods.

3.2. The ARDL bound testing

As we investigate the long-run relationship between CO_2, Ctax, GDP and GDP^2 with mixed stationarity indications, the suitable estimation technique is autoregressive-distributed lag (ARDL) proposed by Pesaran et al. [44]. The ARDL model used in this study is as follows:

$$\begin{aligned}\Delta \ln CO_{2t} = {} & \beta_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln CO_{2t-i} + \sum_{i=1}^{n} \alpha_2 \Delta \ln \mathrm{CTax}_{t-i} \\ & + \sum_{i=1}^{n} \alpha_3 \Delta \ln \mathrm{GDP}_{t-i} + \sum_{i=1}^{n} \alpha_3 \ln \mathrm{GDP}^2_{t-i} \\ & + \pi_1 \ln CO_{2t-i} + \pi_2 \ln \mathrm{CTax}_{t-i} + \pi_3 \ln \mathrm{GDP}_{t-i} \\ & + \pi_4 \ln \mathrm{GDP}^2_{t-i} + \varepsilon_{1t}\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \ln \mathrm{CTax}_t = {} & \beta_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln \mathrm{CTax}_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta \ln \mathrm{GDP}_{t-i} \\ & + \sum_{i=1}^{n} \alpha_3 \ln \mathrm{GDP}^2_{t-i} + \sum_{i=1}^{n} \alpha_4 \Delta \ln CO_{2t-i} \\ & + \pi_1 \ln \mathrm{CTax}_{t-i} + \pi_2 \ln \mathrm{GDP}_{t-i} + \pi_3 \ln \mathrm{GDP}^2_{t-i} \\ & + \pi_4 \ln CO_{2t-i} + \varepsilon_{2t}\end{aligned} \tag{6}$$

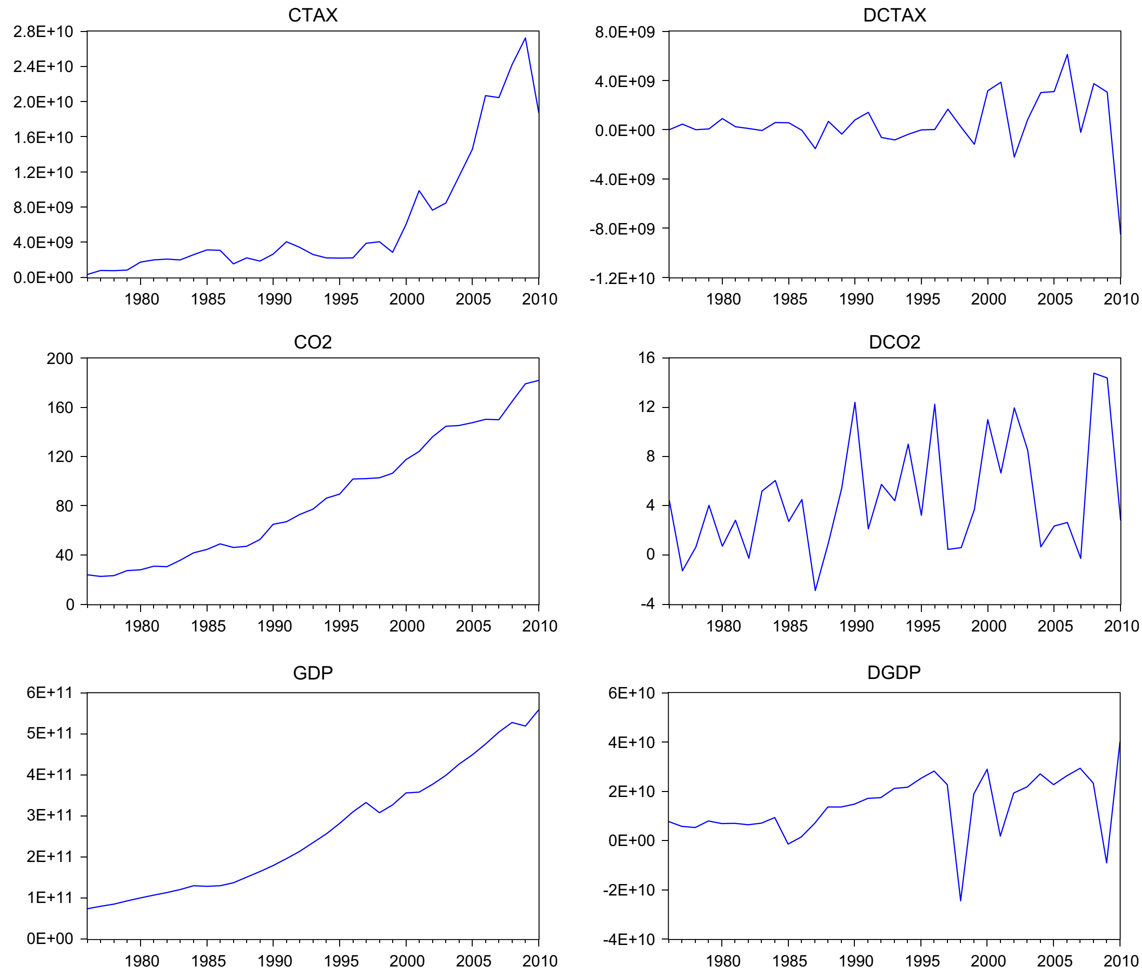

Fig. 1. CO_2, carbon tax revenue and real growth rate.

$$\begin{aligned}\Delta \ln GDP_t = {} & \beta_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_2 \ln GDP^2_{t-i} \\ & + \sum_{i=1}^{n} \alpha_3 \Delta \ln CO_{2t-i} + \sum_{i=1}^{n} \alpha_4 \Delta \ln CTax_{t-i} \\ & + \pi_1 \ln GDP_{t-i} + \pi_2 \ln GDP^2_{t-i} + \pi_3 \ln CO_{2t-i} \\ & + \pi_4 \ln CTax_{t-i} + \varepsilon_{3t} \end{aligned} \qquad (7)$$

$$\begin{aligned}\Delta \ln GDP^2_t = {} & \beta_0 + \sum_{i=1}^{n} \alpha_1 \ln GDP^2_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta \ln CO_{2t-i} \\ & + \sum_{i=1}^{n} \alpha_3 \Delta \ln CTax_{t-i} + \sum_{i=1}^{n} \alpha_4 \Delta \ln GDP_{t-i} \\ & + \pi_1 \ln GDP^2_{t-i} + \pi_2 \ln CO_{2t-i} + \pi_3 \ln CTax_{t-i} \\ & + \pi_4 \ln GDP_{t-i} + \varepsilon_{4t} \end{aligned} \qquad (8)$$

The ARDL model is able to capture the long-run relationship among the variables based on the *F*-statistics (bounds test), where the null hypothesis of level relationship is H_0: $\pi_1 = \pi_2 = \pi_3 = \pi_4 = 0$; against the alternative hypothesis, where the H_1: $\pi_1 \neq \pi_2 \neq \pi_3 \neq \pi_4 \neq 0$. We use the critical values table of Narayan [45] to identify the long-run behaviour of the variables, because the time frame of this study is quite small. As mentioned earlier, one of the main aims of this study is to identify structural breaks; therefore, we include a time trend series of structural break dates based on the ZA unit root test into the ARDL estimation framework to capture the structural break effects in the long-run relationship among the variables. In the second part of the ARDL framework, we explore the short-run relationship with the error correction term, which indicates the speed of adjustment by employing the ARDL-ECM framework with all series integrated at $I(1)$. To ensure the reliability of the ARDL estimation model, we applied the goodness of fit and diagnostic tests as well as the CUSUM and CUSUMsq diagrams.

3.3. *The VECM Granger causality test*

In this study, we use Granger [46] causality estimation based on the ARDL framework by carrying out the ARDL-ECM and the lagged conditions. By applying this framework, we are able to identify the long-run causality based on the error correction term and the short-run causality by conducting the joint *F*-statistic tests. If the error correction term *t*-ratios are statistically significant, this will meet the long-run causalities between the variables. Meanwhile, if the *F*-statistic tests are identically significant, we apply the short-run Granger causality approach for the short-run causal relationship between the variables. The ARDL-ECM models for the Granger causality test in this study can be expressed as follows:

$$\begin{bmatrix} \Delta \ln CO_{2t} \\ \Delta \ln CTax_t \\ \Delta \ln GDP_t \\ \Delta \ln GDP^2_t \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix} + \begin{bmatrix} \delta_{11,1} & \delta_{12,1} & \delta_{13,1} & \delta_{14,1} \\ \delta_{21,1} & \delta_{22,1} & \delta_{23,1} & \delta_{24,1} \\ \delta_{31,1} & \delta_{32,1} & \delta_{33,1} & \delta_{34,1} \\ \delta_{41,1} & \delta_{42,1} & \delta_{43,1} & \delta_{44,1} \end{bmatrix}$$

Table 2
Summary statistics of data (logarithm formation).

	ln CO_2	ln Ctax	ln GDP	ln GDP^2
Mean	4.25	22.02	26.11	682.45
Median	4.34	21.77	26.18	685.57
Maximum	5.20	24.02	27.05	731.72
Minimum	3.11	19.59	25.03	626.59
Std. dev.	0.67	1.074	0.62	32.82
Skewness	−0.26	0.188	−0.13	−0.11
Kurtosis	1.73	2.59	1.66	1.65

Table 3
Unit root tests results.

Variables	Without trend		With intercept and trend	
	ADF	PP	ADF	PP
ln CO_2	−1.24	−3.21**	−1.75	−1.56
Δ ln CO_2	−6.80*	−7.05*	−7.04*	−16.25*
ln Ctax	−2.26	−2.34	−3.22	−3.23
Δ ln CTax	−6.65*	−6.66*	−6.63*	−6.63*
ln GDP	−1.19	−1.16	−1.26	−1.42
Δ ln GDP	−5.18*	−5.19*	−5.44*	−5.45*
ln GDP^2	−0.99	−0.96	−1.40	−1.58
Δ ln GDP^2	−5.25*	−5.26*	−5.43*	−5.44*

* Indicates 1% and 5% significance levels.
** Indicates 1% and 5% significance levels.

Table 4
ZA unit root tests with structural breaks.

Variables	Level		First difference	
	Test value	Year of break (T_B)	Test value	Year of break (T_B)
ln CO_2	−2.14	1990	−5.40*	1990
ln Ctax	−3.81	1987	−6.78*	1997
ln GDP	−3.03	1991	−5.85*	1998
ln GDP^2	−3.95	1991	−5.92*	1998

* Indicates significance at 1% level.

Table 5
CMR unit root test with first difference mean shifts.

Variables	Innovative outliers (IO)			Additive outlier (AO)		
	t-Statistic	$T_B(1)$	$T_B(2)$	*t*-Statistic	$T_B(1)$	$T_B(2)$
ln CO_2	−3.81	1986	2000	5.73*	1987	2001
ln Ctax	−4.58	2000	2004	−6.20*	1997	2004
ln GDP	−3.87	1989	1997	−6.36*	1989	1996
ln GDP^2	−2.55	1990	2003	−7.95*	1990	2003

* Indicates 5% significance level.

Table 6
VAR lag length order selection criteria.

Lag	Log *L*	LR	FPE	AIC	SC	HQ
0	161.9126	NA	1.09e-09	−9.2889	−9.1094	−9.2277
1	277.7949	197.6816*	3.08e-12*	−15.1644*	−14.2665*	−14.8582*
2	293.7182	23.4166	3.23e-12	−15.1598	−13.5437	−14.6087
3	304.0477	12.7599	5.04e-12	−14.8263	−12.4919	−14.0302

LR: sequential modified LR test statistic (each test at 5% level).
FPE: final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.
* Indicates lag order selected by the criterion.

$$\begin{bmatrix} \Delta \ln CO_{2t-1} \\ \Delta \ln CTax_{t-1} \\ \Delta \ln GDP_{t-1} \\ \Delta \ln GDP^2_{t-1} \end{bmatrix} + \dots + \begin{bmatrix} \delta_{11,i} & \delta_{12,i} & \delta_{13,i} & \delta_{14,i} \\ \delta_{21,i} & \delta_{22,i} & \delta_{23,i} & \delta_{24,i} \\ \delta_{31,i} & \delta_{32,i} & \delta_{33,i} & \delta_{34,i} \\ \delta_{41,i} & \delta_{42,i} & \delta_{43,i} & \delta_{44,i} \end{bmatrix}$$
$$\begin{bmatrix} \Delta \ln CO_{2t-i} \\ \Delta \ln CTax_{t-i} \\ \Delta \ln GDP_{t-i} \\ \Delta \ln GDP^2_{t-i} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \end{bmatrix} \times ECT_{t-1} + \begin{bmatrix} \mu_{1,t} \\ \mu_{2,t} \\ \mu_{3,t} \\ \mu_{4,t} \end{bmatrix} \tag{9}$$

In Eq. (9), Δ denotes the difference operator, ECT_{t-1} is the lagged error correction term, $\mu_{1,t}$, $\mu_{2,t}$, $\mu_{3,t}$ and $\mu_{4,t}$ are serially independent random errors.

4. Empirical findings and discussion

The primary test of time series analysis is the stationary identification because time series data are naturally affected by the classical linear regression assumption. Before conducting stationary tests, we explore the basic statistics, as shown in Table 2.

We apply cointegration approaches to examine the long-run relationship between the variables. We note that our variables should be stationary at $I(1)$ or $I(0)$ or the variables are integrated mixed at $I(1)$ and $I(0)$. To ensure that our variables are integrated

Table 7
The ARDL cointegration estimation results.

Variables	ln CO^2	ln CTax	ln GDP	ln GDP^2
F-statistics	7.987**	8.348**	1.2331	4.958
Structural break	1990	1987	1991	1991
Critical values1;#	1% Level	5% Level	10% Level	
Lower bounds	7.527	5.387	4.477	
Upper bounds	8.803	6.437	5.420	
R^2	0.713	0.717	0.999	0.999
Adj-R^2	0.389	0.578	0.998	0.999
F-statistic	2.199***	5.158*	11.144*	22.446*

*,** and *** shows significance at 1%, 5% and 10% levels.
Critical values bounds are from Narayan [45] with unrestricted intercept and unrestricted trend.

Table 8
ECM-ARDL cointegration results.

Dependent variable: CO_2	AIC and SBC: ARDL(1,0,0,0)			
	Coefficient	Standard error	*t*-Statistics	*p*-Value
Long-run estimates				
ln Ctax	0.06	0.03	1.46	0.15
ln GDP	13.94*	4.20	3.31	0.00
ln GDP^2	−0.24*	0.08	−3.06	0.01
Short-run estimates				
Δ ln CTax	0.03	0.02	1.38	0.17
Δ ln GDP	6.83*	2.41	2.81	0.00
Δ ln GDP^2	−0.12*	0.04	−2.68	0.01
ECT_{t-1}	−0.49*	0.12	−3.78	0.01
Panel C: Goodness of fit and diagnostic test statistics				
$\chi^2_{Serial}(1)$	0.01 (0.90)	$\chi^2_{Function}(1)$	0.10 (0.74)	
$\chi^2_{Hetero}(1)$	2.31 (0.13)	$\chi^2_{Normality}(2)$	0.03 (0.98)	

Values in parenthesis are *p*-values.
* and ** indicates 1% and 5% significance levels

at $I(1)$ or $I(0)$, we apply the ADF and PP unit root tests. The results are reported in Table 3.

Table 3 clearly shows that all the variables are stationary with $I(1)$, although the PP test using without trend estimation techniques rejects the null hypotheses at the $I(0)$ stage. In order to determine the stationary level for the unknown structural break, we also apply ZA and CMR, which accommodates a single unknown structural break stemming in the series. We find that all the variables have a unique order of integration in the presence of a structural break in the series. The results are shown in Table 4.

We apply the CMR unit root, which accommodates two unknown structural breaks in the series. The results are reported in Table 5 and we find that the structural breaks suggested by the CMR unit root tests for IO except for CTax in IO are significant at the 5 per cent level of significance. Nonetheless, the AO model that captures sudden changes in the mean of a series seems to be more appropriate for the variables since the results support the significance level at 5% for all variables. With respect to carbon tax revenue, the results show the breakpoint in the years 1997 and 2004. The results suggest that the 1997 Asian Financial Crisis does affect the tax revenue collection. The adoption of the Kyoto Protocol in 1997 by the UNFCCC may also be a contributing factor. However, the increase in the oil price and a new exploration activity in 2000 do not have a significant impact. Although the tax rate remains unchanged since 1998, at 38%, the carbon tax revenue collection has increased due to an increase in world crude oil prices. A few break points recorded in the 1980s are in line with the transformation of Malaysia from a third world country to a young industrialized economy.

Thus an urban-based economic growth has led to increase potential for pollution of the environment. In addition to the adoption of the Montreal Protocol in Malaysia in 1987 marked the beginning of a unique global effort to solve a shared environmental problem further lead to the dropped the ozone-depleting substances (ODS) consumption ([47]). The CMR unit root test also reveals that all the series have a unique order of integration. This suggests applying the ARDL bounds testing cointegration to examine the long-run relationship between the variables over the period from 1974 to 2010 in the case of Malaysia. The results VAR lag length selection along with the ARDL bound test estimation results are shown in Tables 6 and 7, respectively. We use the critical bounds generated by Narayan [45], which are suitable for small data. We find that our computed F-statistic is greater than the upper critical bound at 5%, as we use CO_2 emissions and the carbon tax as dependent variables. This shows that there are two cointegrating vectors, which confirm the existence of the long-run relationship between the variables.

After discussing the existence of the long-run relationship among CO_2 emissions and carbon tax and economic growth, we turn to investigate the marginal impact of carbon tax and economic growth in CO_2 emissions. The results are reported in Table 8. We find that although carbon tax has a positive impact on CO_2 emissions, it is statistically insignificant. This situation arises due to several factors; first, the tax here is imposed on companies that have engaged in petroleum activities, whereas the major producers of CO_2 are the manufacturing companies, and, secondly, the inability of the industry to reduce its dependency on petroleum products to other alternative sources, which are more environmentally friendly. Finally, in order to move into the league of high-income economies, industry has ignored the environmental risks and engaged in high pollution activities to achieve the target. The relationship between economic growth and CO_2 emissions is an inverted U-shaped curve. This shows that a 1% increase in economic growth is linked to a 13.94% rise in CO_2 emissions, while the nonlinear term of GDP seems to confirm the delinking of CO_2 emissions after the threshold level of GDP per capita. This finding is consistent with Saboori et al. [48], who supported the existence EKC in the case of Malaysia.

In the short run (lower segment of Table 8), we find that a carbon tax has a positive impact on CO_2 emissions, although it is still insignificant. The relationship between economic growth and CO_2 emissions is an inverted U-shape, as the linear and nonlinear terms of GDP have a positive and negative impact on CO_2 emissions, and it is statistically significant at the 1% and 5% levels of significance, respectively. The estimate of the lagged error term (ECT_{t-1}) is negative (-0.49), and it is statistically significant at the 5% level. This validates our earlier established long-run relationship between the variables. We may conclude that the adjustment from the short-run to the long-run equilibrium path is 49%, and that it may take approximately two years to reach the equilibrium path. The short model passes all the diagnostic tests easily. We find no evidence of serial correlation or heteroscedasticity. The error term is found to be normally distributed and the functional form of the model is well organized.

For the CUSUM test in Fig. 2, the test statistic is not outside the corridor. On the contrary, the CUSUM of squares test statistic is outside the corridor. Thus, the null hypothesis of parameter stability is rejected at the 5% significance level showing the instability of the coefficients. Structural breaks are a common problem faced by most researchers who have conducted time series data, as, most of the time they are affected by exogenous shocks ([7,8]). In order to explore the significance of the structural breaks arising in this study, we apply the Chow forecast test to capture the effects. Table 9 illustrates the Chow test estimation

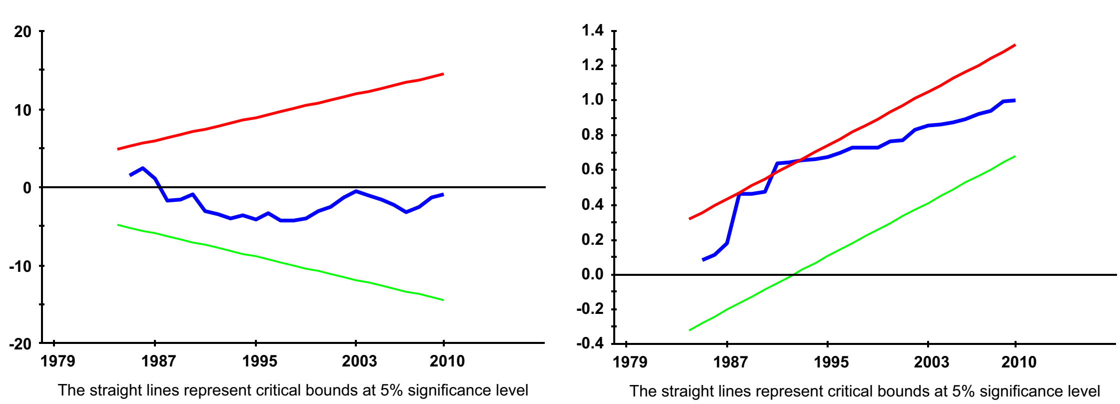

Fig. 2. CUSUM and CUSUMsq.

results, in which there is no significant structural break in the model based on the *F*-statistic value.

We also apply the ARDL-ECM Granger causality to examine the direction of causal relationships between carbon tax, economic growth and CO_2 emissions. It is recommended by Granger [39] to apply the ECM Granger causality framework if the variables are integrated at $I(1)$. There must be causality at least from one direction if the variables are cointegrated. The results are reported in Table 10. We find that carbon tax Granger causes CO_2 emissions, and, in return, CO_2 emissions Granger cause carbon tax in the long run. The unidirectional causality exists running from economic growth to CO_2 emissions. This finding is consistent with Saboori et al. [48] in the case of Malaysia. In the short run, economic growth Granger causes CO_2 emissions. The neutral effect is found between carbon tax and CO_2 emissions. The nonlinear term of GDP also Granger causes carbon tax.

5. Conclusion and policy implications

The Malaysian government has actively taken initiatives to promote the adoption of green technology, as part of a strategy for sustainable development. This effort started in the 1970s with the introduction of the Environmental Quality Act, 1974 to protect the environment from heavy agricultural activities for the country's development. Years later, with the transformation from agricultural based to manufacturing activities more effort should be taken to combat the environmental problem. Issues pertaining to global warming are now becoming a major concern in that considerable research from various disciplines has focused on this problem. Thus, this paper provides an analysis of the impacts of carbon taxation and economic growth on carbon emissions. We aim to examine whether the policies implemented by the government, specifically through taxation, affect carbon emissions. Based on the outcomes, we can state that the imposition of carbon tax in Malaysia is not having much impact on the reduction of carbon emissions. This means that a carbon tax has no significant development on the growth of carbon emissions. This may be due to the structure of taxation in Malaysia, in that companies are either charged a petroleum tax or company tax based on their core activities, and there is no specific tax or policy to cater for carbon emissions. Thus, the companies that are involved in activities that produce large amounts of carbon emissions might not be imposed a petroleum tax.

Meanwhile, in the Tenth Malaysia Plan [49], the Malaysian government has introduced five strategic pillars for a new energy policy. The first strategy is energy pricing for petroleum products, natural gas, electricity and coal. The second strategy relates to the supply side initiatives, especially for imports of LNG and coal, with an emphasis on renewable energy, and the government also accepts nuclear as an option for electricity generation in the future. The third strategy is most likely related to energy efficiency measures in industrial, commercial and residential areas, as well as the transport industry. This is a good policy because these sectors are the largest consumers of energy in Malaysia and have high potential of CO_2 emissions from the generation of electricity from resources. The fourth energy policy relates to stronger governance that can be emphasized by increasing the market disciplines for natural resources and electricity generation. This will guide industries and consumers in Malaysia to be more responsible and disciplined while dealing with non-renewable and renewable resources. The fifth new energy strategy is mostly related to managing energy resources by integration and a sequenced approach to achieve sustainable outcomes. In conclusion, this new energy policy introduced through the Tenth Malaysia Plan [49] is a wonderful idea to reduce CO_2 emissions from energy generation in the future as well as guiding industries and consumers through the dynamic link between resources and environmental sustainability.

However, the empirical results suggest that economic growth in Malaysia affects carbon emissions. The results are consistent in both the short run and long run. This supports Kuznets' theory in that the more developed the country, the more concern given to combat environmental pollution. However, on reaching the developed status less concern is given to environmental issues. Referring to our data, we can classify the data in three phases – 1970s, 1980s, 1990s and onwards. In the 1970s, Malaysia relied heavily on agricultural activities that emitted less carbon. However, due to privatization and transformation to manufacturing activities in the mid-1980s, the production of carbon emissions increased. With the government's aim to attain developed nation status in 2020, it is expected that the production of carbon emissions will increase to 180 million metric tons per year in 2010 as compared to only

Table 9
Chow forecast test.

Length of period: 1980–2010		
	Statistics	*p*-Value
F-statistic	2.728	0.450
Log likelihood ratio	155.373*	0.000

* and ** indicates 1% and 5% significance levels.

Table 10
Granger causality estimations under the ARDL approach.

Dependent variable	Weak causality (χ^2 statistics)					Strong causality (χ^2 statistics)			
	Short run Granger causality				Long run	Δ ln CO_2 and ECT_{t-1}	Δ ln CTax and ECT_{t-1}	Δ ln GDP and ECT_{t-1}	Δ ln GDP^2 and ECT_{t-1}
	Δ ln CO_2	Δ ln CTax	Δ ln GDP	Δ ln GDP^2	ECT_{t-1}				
Δ ln CO_2	–	1.92 (0.16)	7.94 (0.01)*	7.23 (0.01)*	−0.49 (−3.78)*	–	14.39 (0.00)*	15.07 (0.00)*	15.08 (0.00)*
Δ ln CTax	0.82 (0.36)	–	3.66 (0.06)	4.22 (0.04)**	−0.32 (−2.38)**	4.15 (0.12)	–	4.10 (0.12)	8.51 (0.03)**
Δ ln GDP	0.13 (0.71)	0.86 (0.35)	–	8.18 (0.00)*					
Δ ln GDP^2	0.15 (0.69)	0.81 (0.36)	8.18 (0.00)*	–					

Values in parenthesis are *p*-values.

* Indicates 1%, 5% and 10% significance levels.

** Indicates 1%, 5% and 10% significance levels.

14 million metric tons in 1974. Therefore, although the government has put much effort by introducing incentives to counter the environmental issues, support from other parties, such as companies and individuals, is vital. Vigorous enforcement of the existing regulations in order to keep pace with the anticipated growth in investments is crucial to counter the environmental problems. The government should also focus on being a facilitator that provides a platform for industry to play its role in undertaking special environmental and ecological campaigns, which will benefit both parties. In recent years, the government has also played an important role by reducing the import tax on green technology imported cars, especially from Japan. This is a good indication that the Malaysian government has a positive intention to reduce CO_2 emissions. However, it is hoped that once Malaysia achieves developed nation status by 2020, its view concerning environmental issues will change accordingly.

Conversely, some of the previous studies argued about the contribution of the various sectors to economic growth and the pressure on environmental sustainability. To overcome this conundrum, the taxation policy on non-renewable resources, such as petroleum, gas and coal, should be revised. This can be emphasized through fiscal policies that incorporate carbon tax policies because the findings of this study have not been able to capture the contribution of taxation on CO_2 emissions. From our point of view, by utilizing carbon tax policy, the government able to sustained continuous economic growth with tax revenue with hoping more of industrial activities that have direct connection with environmental hazards. As a developing country, economic growth and CO_2 emissions is following the basic Kuznets theory. Basically, a carbon tax is one of the important policies choices to stimulate the realization of CO_2 in many developed and developing countries ([29]). In addition, the positive impact on economic growth from carbon tax revenue should be discussed based on the traditional Kuznets theory. From the findings of this study, the impact on tax revenue is directly related to the economic growth scenario. Therefore, if we introduce an environment taxation policy on non-renewable resources, conversely, it will not reduce the CO_2 emissions. This is because Malaysia is facing an upward trend of the Kuznets curve, such that an increase in the economic growth will tend to increase CO_2 emissions. Finally, in conclusion, a carbon tax policy is able to sustain the economic growth in Malaysia, but is not able to reduce the environmental hazards caused by the high volume of industrial activities. Whatever the results of this study indicate, the top priority is to combat CO_2 emissions in Malaysia by encouraging the innovative green technology aspects of the industrial, commercial, and residential areas, as well as the transport industry. In the meantime, the government should play an important role with policy implications, especially in the urban areas to reduce energy use, and the citizens must be more responsible for achieving a sustainable environment.

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